REPORT MAB-196-M

64-12

437606

Recommended Quality Standards for Tungsten Sheet Produced in the Refractory Metals Sheet Rolling Program

437606

ADVICE TO THE GOVERNMENT ON MATERIALS RESEARCH AND DEVELOPMENT

MATERIALS ADVISORY BOARD

National Academy of Sciences—
National Research Council
Washington, D. C.

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OFFICES:
1155 16TH STREET, N.W.

January 22, 1964

Dear Sir:

I am forwarding herewith the report entitled "Recommended Quality Standards for Tungsten Sheet Produced in the Refractory Metals Sheet Rolling Program" by the Subpanel on Quality Specifications of the Refractory Metals Sheet Rolling Panel, which has been submitted through the National Academy of Sciences-National Research Council to the Director of Defense, Research and Engineering. This report has been reviewed by the Refractory Metals Sheet Rolling Panel and by individual members of the Materials Advisory Board who have competence in the field.

In accordance with an agreement with the Office of the Director of Defense, Research and Engineering, this report is being distributed on the same date it is being transmitted to the Department of Defense. Therefore, as of this date, it has not been reviewed by the Office of the Director of Defense, Research and Engineering.

Very truly yours,

Carl S. Marvel, Chairman
Materials Advisory Board

Enclosure

MAB-196-M

Report of the

Subpanel on Quality Specifications

Refractory Metals Sheet Rolling Panel

Materials Advisory Board

RECOMMENDED QUALITY STANDARDS FOR TUNGSTEN SHEET PRODUCED IN THE REFRACTORY METALS SHEET ROLLING PROGRAM

Division of Engineering and Industrial Research
National Academy of Sciences
National Research Council
Washington 25, D. C.

January 22, 1964

This report prepared and submitted to the Office of the Director of Defense Research and Engineering under ARPA Contract Number SD-118, between the Department of Defense and the National Academy of Sciences.

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FOREWORD

This revised sheet quality "specification" differs from MAB-184-M (Report of the Subpanel on Quality Specifications) in that it is limited to tungsten, and includes tensile property minimum values. These tensile minimums reflect realistic producer capabilities as demonstrated by the Navy contract NOw-60-0621-c with the Fansteel Metallurgical Corporation; and as such should be of particular interest to aerospace weapons designers.

These quality standards apply in general to sheet which is to be used in the as-furnished condition. Quality sampling specifications for plate, such as would be used in shear spinning, are covered in another publication (MAB-190-M). The plate produced under the Refractory Metal Sheet Rolling Program was insufficient to permit the establishment of minimum tensile or ductility values. Sheet destined for drastic working operations, such as cupping or drawing, might require a different microstructure (retaining a greater capacity for additional deformation) than that corresponding to the material in this report. For such other applications, the mechanical property levels would not correspond to those of the heavily cold worked sheet covered in these standards. Further experimental work would be required to define these property levels.

TUNGSTEN SHEET STANDARDS

SCOPE

1. This standard, written in the manner of a specification, describes tungsten sheet produced under contract from the Department of Defense in its Sheet Rolling Program.

PRODUCT LIMITATIONS

2. Any product between 0.187 and 0.005 inch inclusive in thickness, and 5 inches or more in width, is classified as sheet. All sheet shall be furnished in the stress-relieved condition.

IDENTIFICATION

3. a. All sheets shall be identified in the middle of each side of each sheet by this specification number, producer, sheet serial number, lot number, and nominal gage. A suitable marking fluid shall be used which can be removed with a cleaning solvent and which shall have no deleterious effect on the material.

   b. The sheet serial numbers shall run consecutively and be identified by the manufacturer in an accompanying report as to heat number and position of that sheet in the original ingot, e.g., top, middle, or bottom. In the case of powder metallurgy consolidation, billet rather than heat shall be identified.

   c. The lot is defined as follows for arc-melted or powder metallurgy consolidated material:

      (1) Arc Melted Consolidation

      All sheets of the same nominal thickness from the same heat with final rolling and both pre- and post-final rolling thermal treatments at the same time.

c. (Continued)

(2) Powder Metallurgy Consolidation

All sheets of the same nominal thickness with final rolling and both pre- and post-final rolling thermal treatments at the same time which have been made from billets pressed from a given blend of powders and sintered at the same time in a batch sintering operation, or during a given eight-hour shift in a continuous sintering operation, provided that the temperature and time of sintering are identical.

SAMPLING

4. a. All sheets produced by a contractor shall receive 100 per cent inspection visually, dimensionally, and sonically as described herein. In addition, one transverse bend test shall be made from one end of each sheet. The test temperature shall be as shown in Table VIII for the gage tested. The material for this test shall be excess from the end of the sheet and shall not diminish the size of the sheet ordered.

b. With the exception of those tests described in paragraph 4. a., above, the number of sheets which shall be tested in any given lot are listed in Table I according to the size of the lot.

TABLE I - SAMPLING

Sheets Per Lot	Sheets Tested Per Lot
1	1
2 - 10	2
11 - 20	3
Over 20	4

c. Table II indicates the number and size of test specimens which shall be taken from each sheet to be tested.

d. Figure 1 shows the location of test specimens which shall be taken from each sheet to be tested.

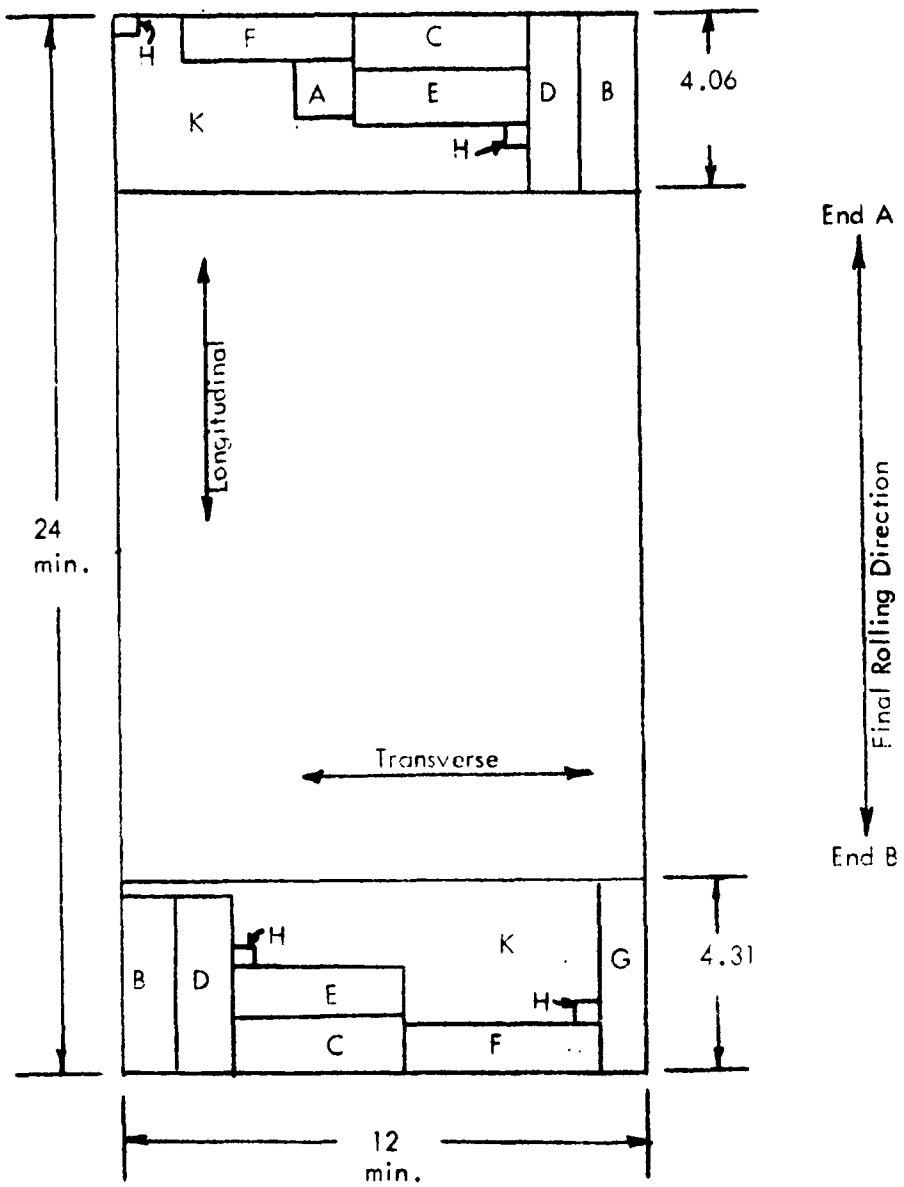
TEST PROCEDURES

5. All tests will be performed in accordance with the "Evaluation Test Methods for Refractory Metal Sheet Material" by the Subpanel on Standardization of Test Methods, MAB Refractory Metals Sheet Rolling Panel. (Report MAB-192-M, dated April 22, 1963), or the latest revision thereof.

TABLE II
Sheet Sampling

Section No.	Test Name	Size of Specimen Blank, Inches	No. of Specimens Per Sheet	Fig. 1 Code No.
6.	Visual	Whole Sheet	Whole Sheet	-
7.	Dimensional	Whole Sheet	Whole Sheet	-
8.	Sonic	Whole Sheet	Whole Sheet	-
9.	Chemical	1.5 x 1.5	1	A
10.	Tensile			
10. a.	Longitudinal, 1000F	1.25 x 4	2	B
10. a.	Transverse, 1000F	1.25 x 4	2	C
10. b.	Longitudinal Notched, 1000F	1.25 x 4	2	D
10. c.	Tensile, Transverse 2000F	1.25 x 4	2	E
11.	Bend Test, Transverse	1 x 4.25	2	F
	Longitudinal	1 x 4.25	1	G

FIGURE 1
Specimen Sampling



Dimensions allow for 1/16 inch saw cuts.

K Excess material for additional tests as required.

Note: Wider cuts may be taken, if dimensions permit.

Section No.	Test Name	Size of Specimen Blank, Inches	No. of Specimens Per Sheet	Fig. 1 Code No.
12.	Metallographic and Hardness Longitudinal or Transverse	0.5 x 0.5	4	H

VISUAL INSPECTION

6. All sheets on any one purchase order shall be furnished with the same finish treatment, e.g., pickled. Sheets which contain pits, cracks, scratches, non-metallic inclusions, or "fish scale" markings are unacceptable. Surface imperfections may be removed before shipment, but such removal shall not reduce the thickness of the material below that permitted by the tolerance for the thickness ordered. Such removal must be accomplished prior to final finish treatment, e.g., pickling.

DIMENSIONAL TOLERANCES

7. a. Tolerances on width shall be ± 1/16 inch.

   b. Tolerances on length shall be ± 3/16 inch.

   c. Tolerances on thickness shall be as shown in Table III below. Measurements shall be taken one inch in from the edges on all sheets at the corners and mid sides to the nearest .0001 inch.

TABLE III
Thickness Tolerances ±

Nominal Gage, Inches	Nominal Width, Inches		
	5 to 10	Over 10 to 18	Over 18
.005	.0007	.0007	.0010
Over .005 to .007	.0007	.00085	.0015
Over .007 to .016	.001	.0015	.002
Over .016 to .026	.0015	.0025	.003

TABLE III (Continued)

Nominal Gage, Inches	Nominal Width, Inches		
	5 to 10	Over 10 to 18	Over 18
Over .026 to .040	.002	.003	.004
Over .040 to .058	.003	.004	.005
Over .058 to .072	.004	.005	.006
Over .072 to .083	.004	.006	.007
Over .083 to .098	.004	.007	.0075
Over .098 to .114	.005	.007	.008
Over .114 to .130	.005	.008	.010
Over .130 to .145	.006	.008	.010
Over .145 to .187	.007	.009	.010

d. Edge camber shall be 3/16 inch maximum in 8 feet.

e. Flatness deviation tolerances shall be as shown in Table IV. Flatness deviation shall be determined by the method shown in Figure 2. The actual values shall be reported. In determining flatness the sheet shall not be subject to external pressure at any point, but shall be allowed to lie freely on a flat surface during measurement.

TABLE IV
Flatness Deviation Tolerances

Nominal Gage, Inches	Tolerance, %
.005	6
Over .005 to .015 inclusive	6
Over .015 to .025 inclusive	5
Over .025 to .040 inclusive	5
Over .040 to .060 inclusive	5
Over .060 to .100 inclusive	4
Over .100	4

SONIC INSPECTION

8. Determination of the presence of definite laminations in the sheets will be accomplished with sonic inspection techniques. A grid pattern no more than two inches on a side will be used for the survey. Laminated areas will be marked on the sheet. Sheets showing such areas will be subject to rejection at the discretion of the contracting agency.

CHEMISTRY

9. Chemical determinations shall be made on individual sheets representative of each lot in accordance with Tables I and II. Sampling shall be made in accordance with Figure 1. Analysis will be made for the principal impurity elements and the three interstitial elements: oxygen, nitrogen, and carbon. Maximum permissible impurity levels are as shown in Table V.

TABLE V
Chemistry Allowables, ppm Maximum

Element	ppm, Max.	Element	ppm, Max.
C	50	Sn	20
O	50	Ca	20
N	20	Co	10
H	10	Pb	10
Mo	100	Mg	10
Fe	50	Mn	10
Si	40	Ag	10
Al	40	V	10
Zr	50	Ti	10
Cr	20		
Ni	20		
Cu	20		

Tungsten 99.95% minimum, by difference

TENSILE PROPERTIES

10. a. Transverse and longitudinal 1000°F tensile specimens shall be taken from each end of each sheet selected in accordance with

a. (continued)

Table I and cut as shown in Figure 1. The allowable variation for all specimens in any one lot shall not be greater than that shown in Table VI. The minimum value for any test shall not be less than that shown in Table VII.

b. Longitudinal notched 1000°F tensile specimens shall be taken from each end of each sheet selected in accordance with Table I and cut as shown in Figure 1. The notched-unnotched tensile ratio shall not be less than one.

c. Transverse 2000°F tensile specimens shall be taken from each end of each sheet selected in accordance with Table I and cut as shown in Figure 1. The allowable variation for all specimens in any one lot shall not be greater than that shown in Table VI. The minimum value for any test shall not be less than that shown in Table VII.

TABLE VI
Tensile Property Tolerances

Property	Variation from Average for Lot
Ultimate Tensile Strength, 1000°F	
Longitudinal	± 15%
Transverse	± 12%
Tensile Yield Strength, 1000°F	
Longitudinal	± 20%
Transverse	± 12%
Ultimate Tensile Strength, 2000°F	
Transverse	± 20%
Tensile Yield Strength, 2000°F	
Transverse	± 20%

TABLE VII

Tensile Property Minimum Values

Test	Temperature °F	Direction*	Nominal Gage, inches				
			.010-.019	.020-.039	.040-.079	.080-.124	.125-.187
Ultimate Tensile Strength, ksi	1000	T	130	120	85	75	75
	1000	L	120	110	75	75	75
	2000	T	75	75	60	60	60
Tensile Yield Strength - ksi	1000	T	100	100	70	60	60
	1000	L	90	90	60	60	60
	2000	T	60	60	50	50	50
Elongation, % in 1 in.	1000	T	4	5	6	6	6
	1000	L	4	5	6	6	6
	2000	T	6	6	6	6	6

* L = Longitudinal

T = Transverse

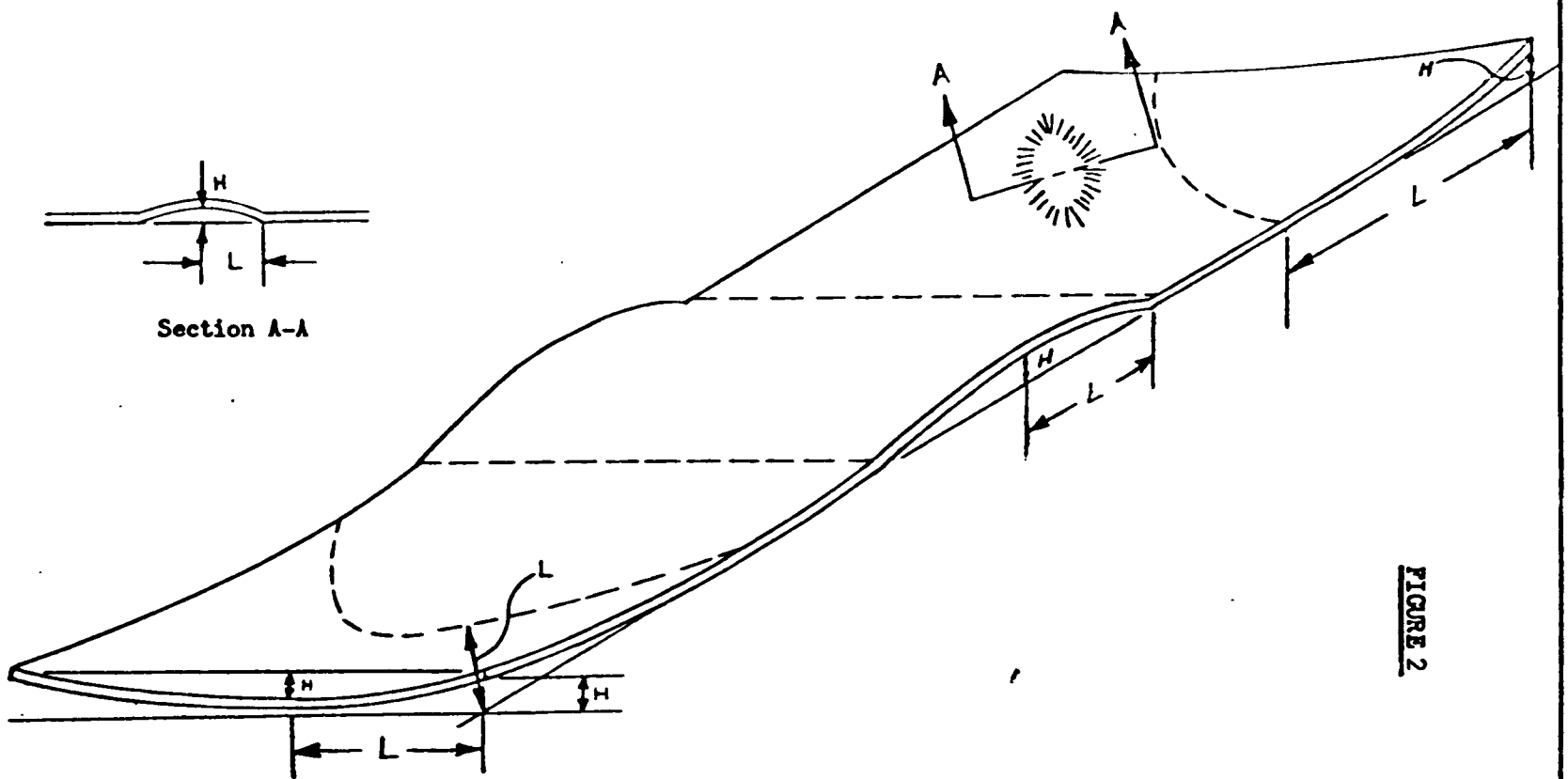


FIGURE 2

H = Maximum Distance Between Flat Surface and Lower Surface of Sheet.

L = Minimum Distance Between Highest Point on Sheet and Point of Contact with Flat Surface.

———— Line of Tangency Between Sheet and Flat Surface.

H/L X 100 = % Flatness Deviation

BEND TEST

11. a. Transverse and longitudinal bend specimens shall be taken from each end and from one end, respectively, from each sheet selected in accordance with Table I and cut as shown in Figure 1. Tests shall be made using a 4T (T = thickness) bend radius at the temperature indicated in Table VIII for the gage tested. If any of the specimens fail to bend to 90° at temperature, the lot shall be subject to rejection.

b. In addition to the above, one transverse bend specimen shall be taken from one end of each sheet (see paragraph 4.a.) in the lot and tested as described above. Failure to pass the above test subjects that particular sheet to rejection independently of results obtained from lot sampling tests.

METALLOGRAPHIC AND HARDNESS

12. a. Metallographic specimens shall be taken in accordance with Table I and Figure 1 for information only to determine structure (average grain diameter, if recrystallized) and the occurrence of solid non-metallic inclusions or intermetallic compounds. Photomicrographs shall be taken on all specimens at 250X and at 1000X.

b. Diamond pyramid hardness readings shall be taken on all metallographic specimens in the middle of the section. The load shall be recorded.

REPORTS

13. It is recommended that the format of the reports follow the example given in Figure 3 and be furnished to the contracting officer.

TABLE VIII
Maximum Permissible Bend Test Temperature
(Bend Radius = 3X thickness)

Nominal Gage, Inches	Test Specimen Direction*	Maximum Temperature, °F
.005 to .020 inclusive	L	300
.005 to .020 inclusive	T	400
Over .020 to .040 inclusive	L	400
Over .020 to .040 inclusive	T	500
Over .040 to .100 inclusive	L	500
Over .040 to .100 inclusive	T	600
Over .100 to .187 inclusive	L	600
Over .100 to .187 inclusive	T	700

* L = longitudinal, T = transverse

FIGURE 3
Sheet Test Report

Alloy: _____ Sheet Serial No.: _____

Producer: _____ Lot No.: _____

P. O. Number: _____ *Heat No.: _____

Condition: _____ **Position in Ingot: _____

Month and Year Produced: _____ Sheet Size (Nom.)

Gage: _____

Length: _____

Width: _____

Visual Inspection:

Dimensional:

Length: _____

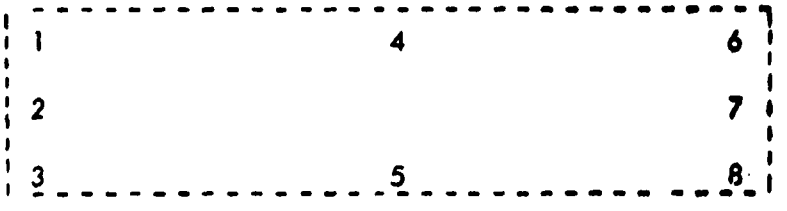
Width: _____

Camber: _____

Thickness: 1 _____ 2 _____ 3 _____

4 _____ 5 _____ 6 _____

7 _____ 8 _____



Flatness Deviation: _____

Oil Can: _____

Sonic: _____

Chemistry of Sheet:

Impurity: 1 _____ 2 _____ 3 _____ 4 _____

5 _____ 6 _____ 7 _____ 8 _____

Interstitial: O _____ N _____ C _____

* In the case of powder metallurgy consolidation - "Billet No."
** In the case of powder metallurgy consolidation - "Density of Billet: ____%"

Tensile Properties	Ultimate, psi	Yield, psi	Elong., % in ____
1000°F			
End A, Transverse	_____	_____	_____
End A, Longitudinal	_____	_____	_____
End B, Transverse	_____	_____	_____
End B, Longitudinal	_____	_____	_____
2000°F			
End A, Transverse	_____	_____	_____
End B, Transverse	_____	_____	_____
1000°F Notched			
End A, Longitudinal	_____	_____	_____
End B, Longitudinal	_____	_____	_____

Bend Te.: (°F, see Table VIII)	Bend, Degrees	Springback, Degrees	°F
End A, Transverse	_____	_____	_____
End B, Transverse	_____	_____	_____
End B, Longitudinal	_____	_____	_____

Metallographic Results:

Structure: _____

Average Grain Diameter: _____

Inclusions: _____

Hardness Results:

Readings, DPH	_____	_____	_____	_____
Average, DPH	_____			
Load, grams	_____			

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NATIONAL ACADEMY OF SCIENCES—
NATIONAL RESEARCH COUNCIL

The National Academy of Sciences—National Research Council is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare.

The Academy itself was established in 1863 under a Congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

The National Research Council was established by the Academy in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government, and a number of members-at-large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contributions, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.

MATERIALS ADVISORY BOARD

The Materials Advisory Board is a part of the Division of Engineering and Industrial Research of the Academy-Research Council. It was organized in 1951 under the name of the Metallurgical Advisory Board, with assignments from the then existing Research and Development Board of the Department of Defense. At that time, the Research and Development Board requested the Board to accept tasks covering a broad spectrum of metallurgical science and technology as related to the Armed Services, and to include certain other areas such as collection and dissemination of information, and cooperation with professional societies in publication of significant metallurgical data.

Since the organization date, the above scope has been expanded to include organic and inorganic nonmetallic materials, and the name has been changed to the Materials Advisory Board. Concurrently, the Board's membership, staff, and operations have been adjusted to encompass the greater diversity of materials and to concentrate on materials research and development, excluding other activities except to the extent that they support and strengthen the Board's fulfillment of its primary responsibility.

The Office of the Director of Defense Research and Engineering, Office of the Secretary of Defense, is the government agency which now requests specific consulting and advisory services under this broadened program. Under a contract between the Office of the Secretary of Defense and the National Academy of Sciences, the Board's assignment is:

> ". . . at the written request of the Director of Defense Research and Engineering, or his designated representative, to conduct studies, surveys, make critical analyses, and prepare and furnish to the Director of Defense Research and Engineering advisory and technical reports, with respect to the entire field of materials research, including the planning phases thereof; and shall, in addition, perform such other services as may be agreed upon in writing, from time to time, by the Director of Defense Research and Engineering and the President of the Contractor.
>
> "Task assignments under this contract will be as mutually agreed by the Director of Defense Research and Engineering or his designated representative and the Contractor. Recommendations for tasks may be proposed to the Director of Defense Research and Engineering by agencies of the Military Departments, the Office of the Secretary of Defense, or the Contractor."